Final results of a Dark Matter Search with the Silicon Detectors of the CDMS II experiment and future results from SuperCDMS Soudan/SNOLAB

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TAUP conference
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Massachusetts Institute of Technology

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The SuperCDMS Collaboration

Time

See R. Nelson talk

CDMS II (Ge+Si)

- 4.6 kg Ge (19 x 240 g)
- 1.2 kg Si (11 x 106g)
- 35% NR acceptance

SuperCDMS Soudan

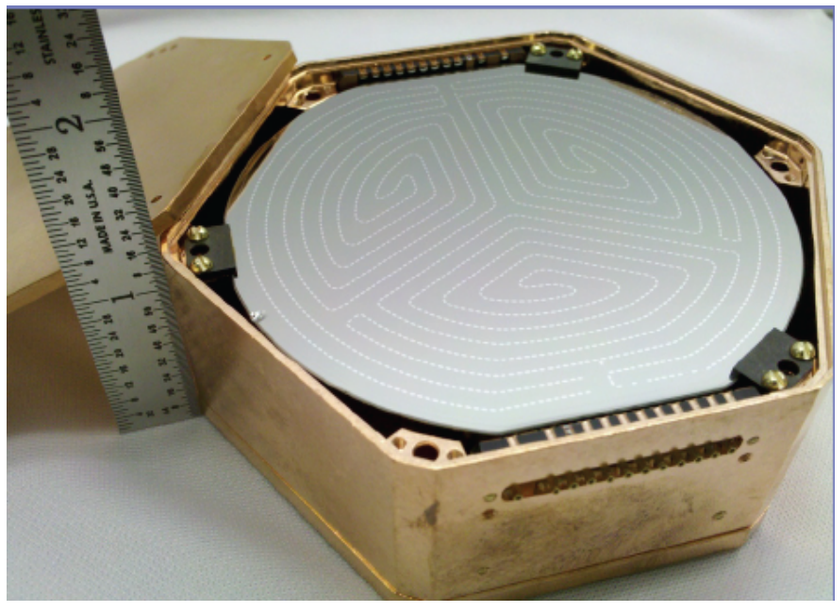
- Increased mass: 9.0 kg Ge (15 x 600 g)
- Increased acceptance
- Improved surface event discrimination

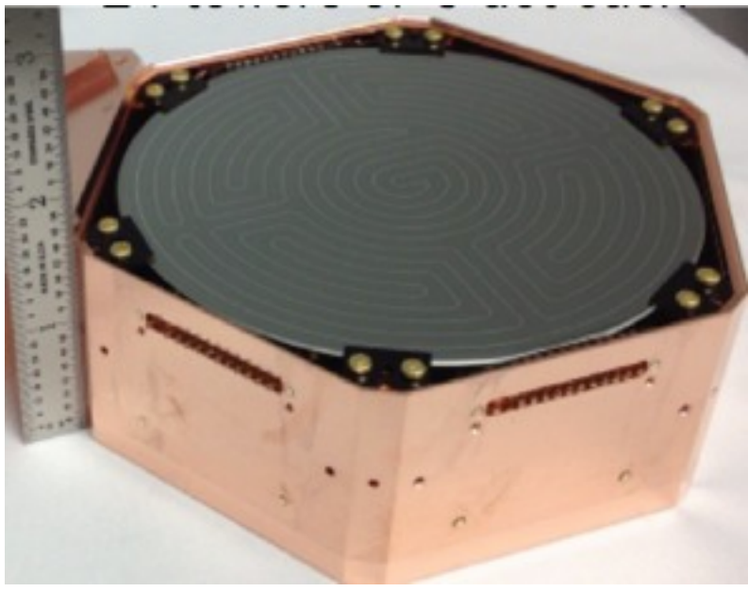
CDMSLite: See J. Hall talk

SuperCDMS SNOLAB

- Proposed 200kg Ge array
- Extensive R&D underway
- Scale to 1 kg crystals

Projected sensitivity of 8 x 10^{-47} cm^2





CDMS II Silicon: Final analysis

See R. Nelson talk

CDMS II (Ge+Si)

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- 1.2 kg Si (11 x 106g)
- 35% NR acceptance

Blind analysis of 140 kg-days of Si data (8 detectors)
July 2007- September 2008

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CDMSLite: See J. Hall talk

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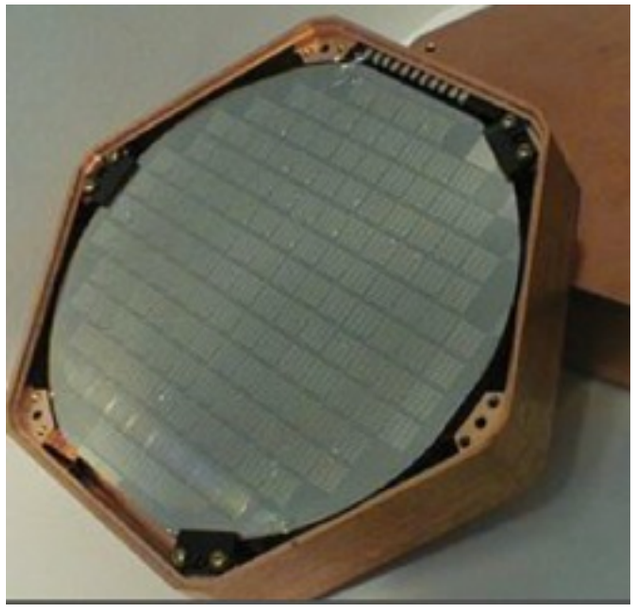
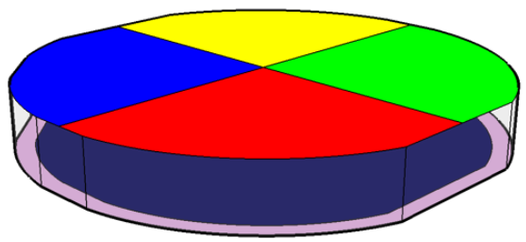
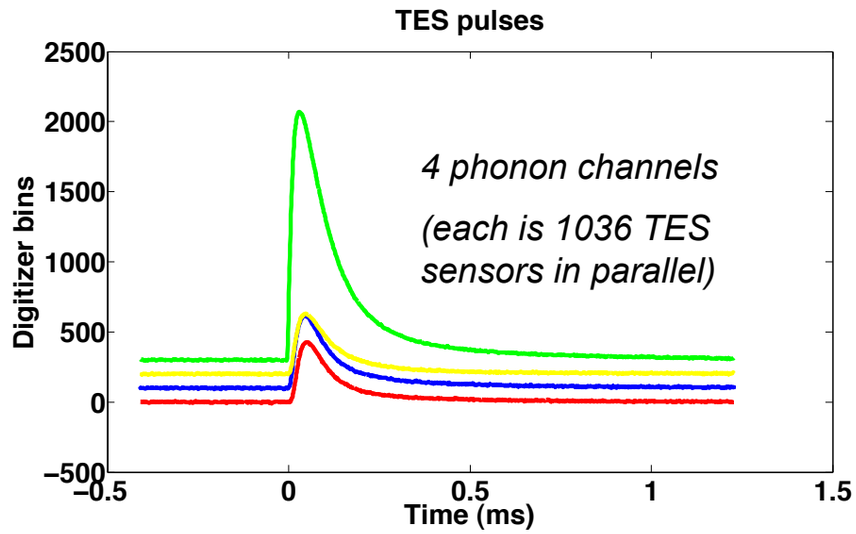
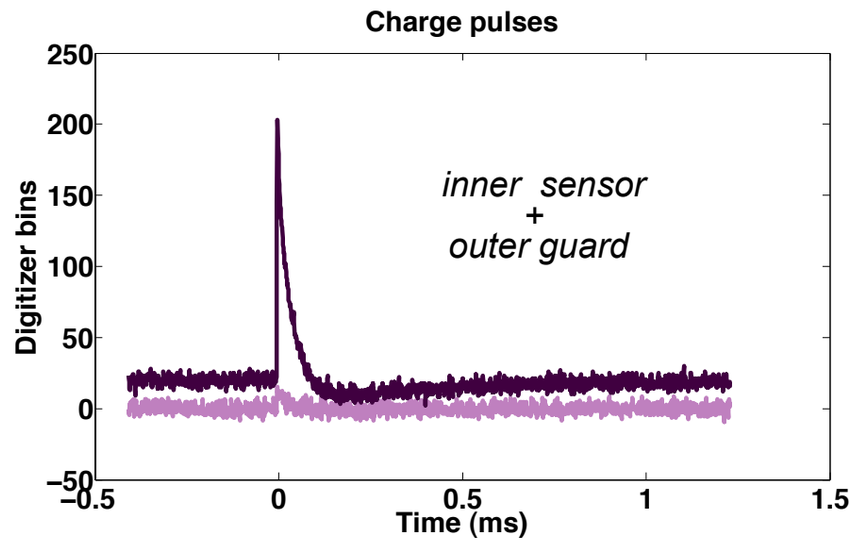
CDMSII ZIP detectors



240 g Ge or 106 g Si crystals
(1 cm thick, 7.5 cm diameter)

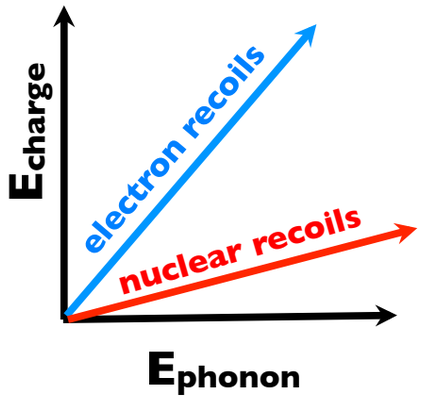






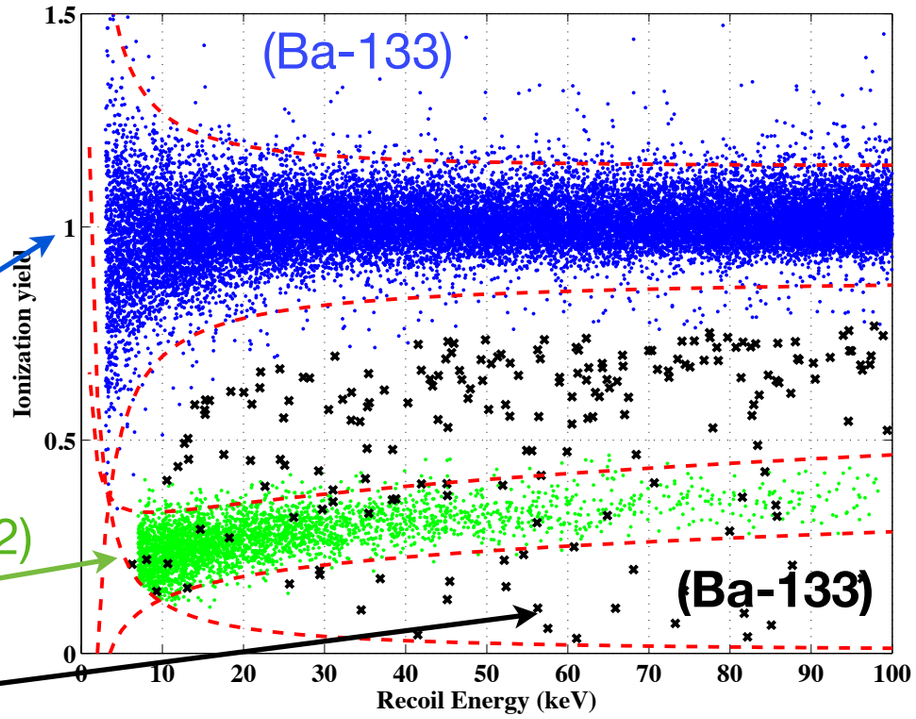
- **Z**-sensitive **I**onization and **P**honon mediated
- Measure both **charge** and **phonon** energy
- Photolithographically patterned to collect athermal phonons and ionization signals
- Direct xy-position imaging
- Surface (z) event rejection from pulse shapes and timing

CDMS strategy



Ionization yield (ionization energy per unit recoil energy) strongly depends on recoil type.

Y = E_charge/E_recoil

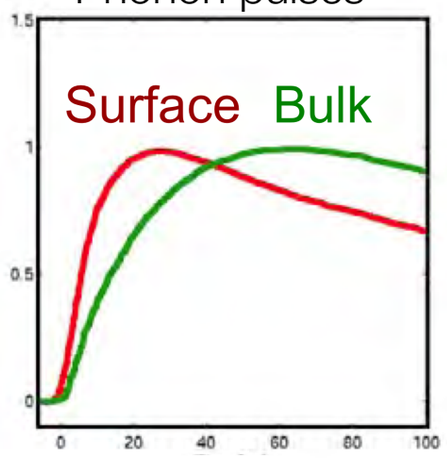


Most backgrounds produce electron recoils: Y = 1

WIMPs and neutrons produce nuclear recoils: Y ~ 0.3

Surface events: reduced ionization yield Y<1

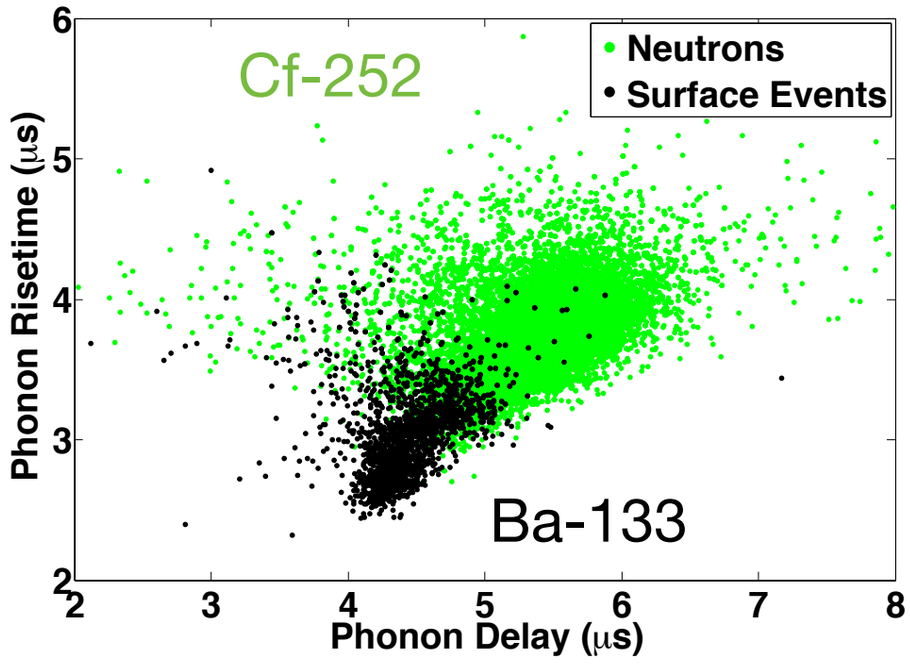
Phonon pulses



Can be rejected through a phonon timing cut

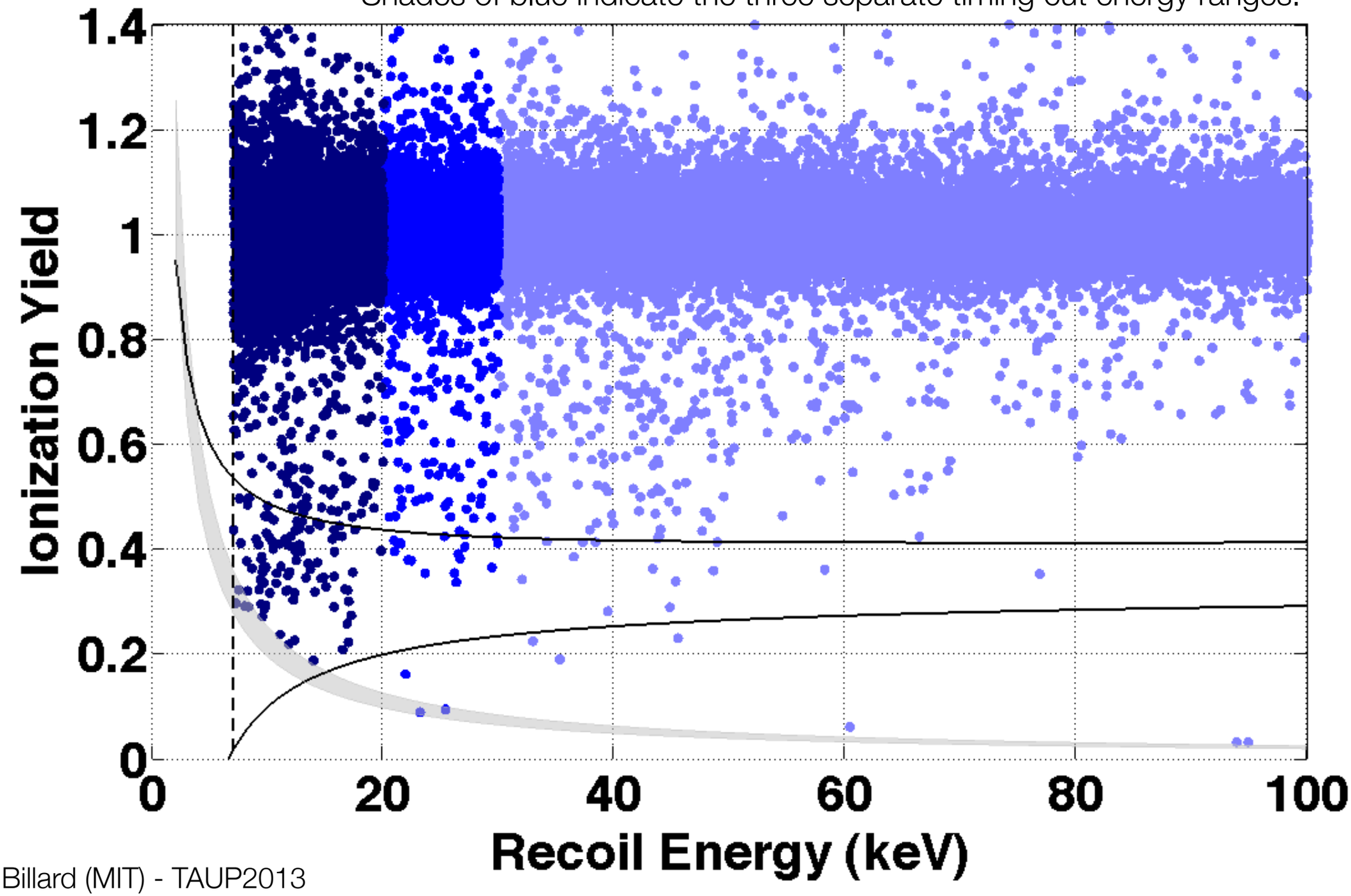
Ionization yield + timing result in <1 in 10^6 electron recoils leaking into the signal region

pre-unblinding leakage estimate of 0.47

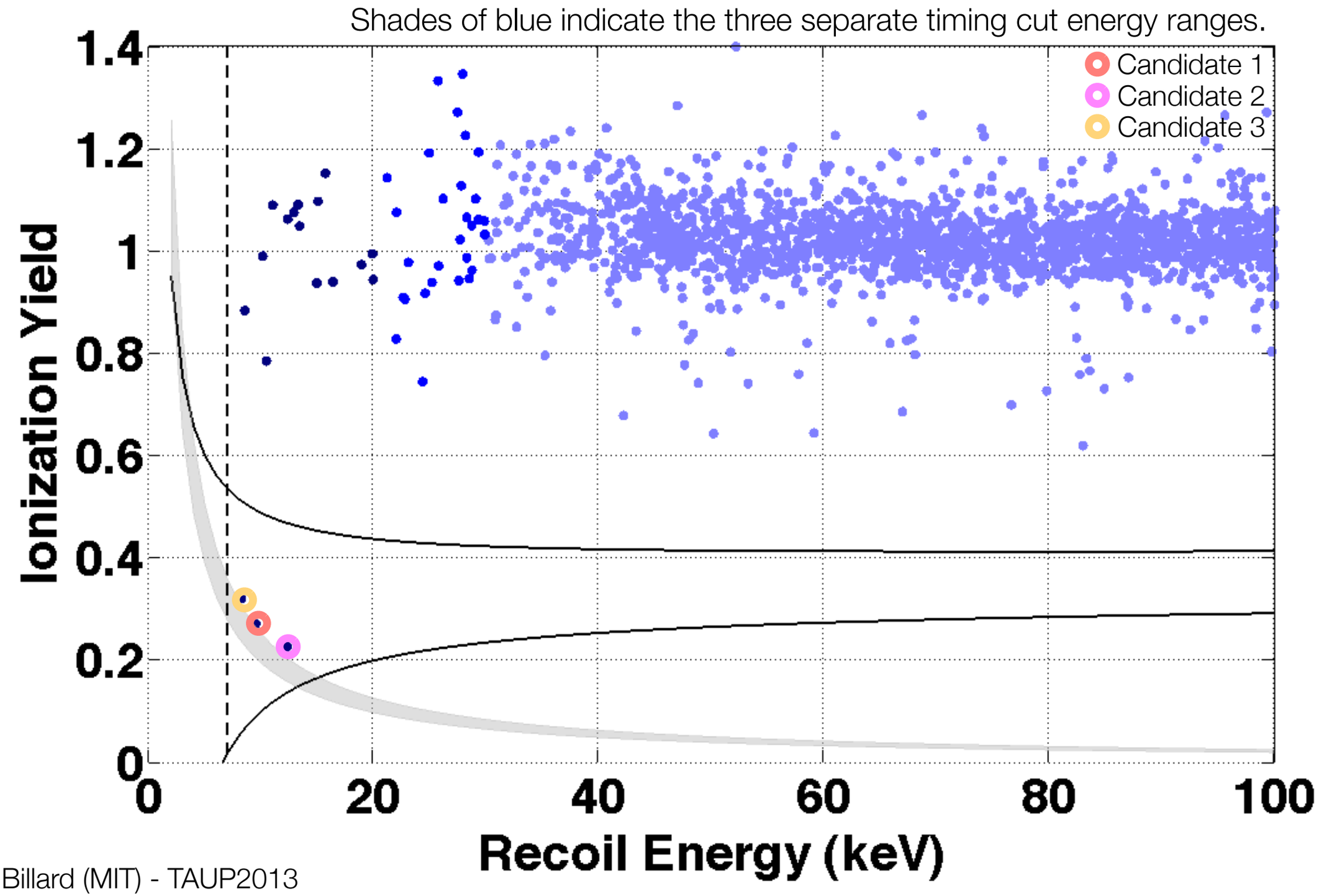


Unblinding Results - before timing cut

Shades of blue indicate the three separate timing cut energy ranges.

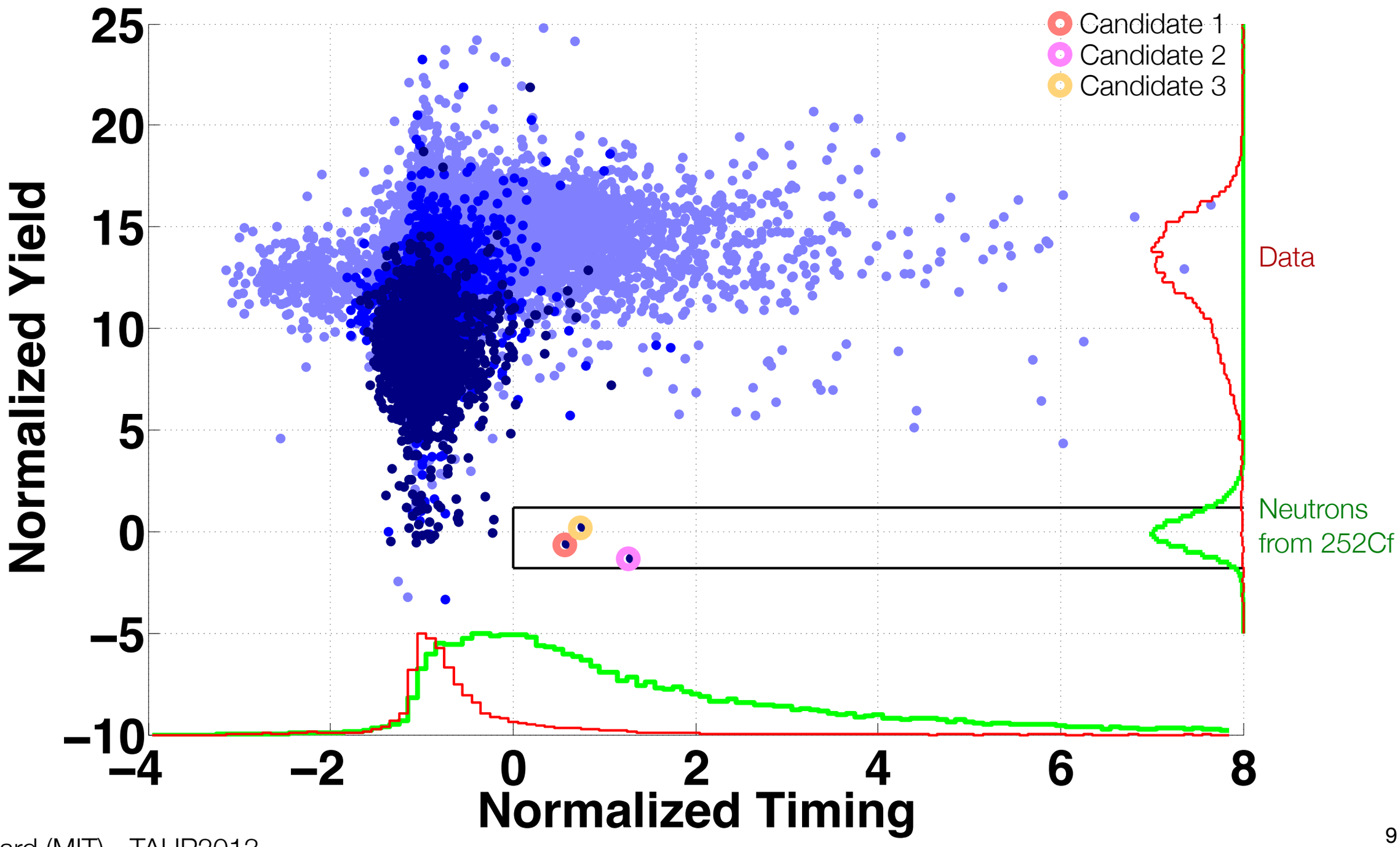


Unblinding Results - after timing cut



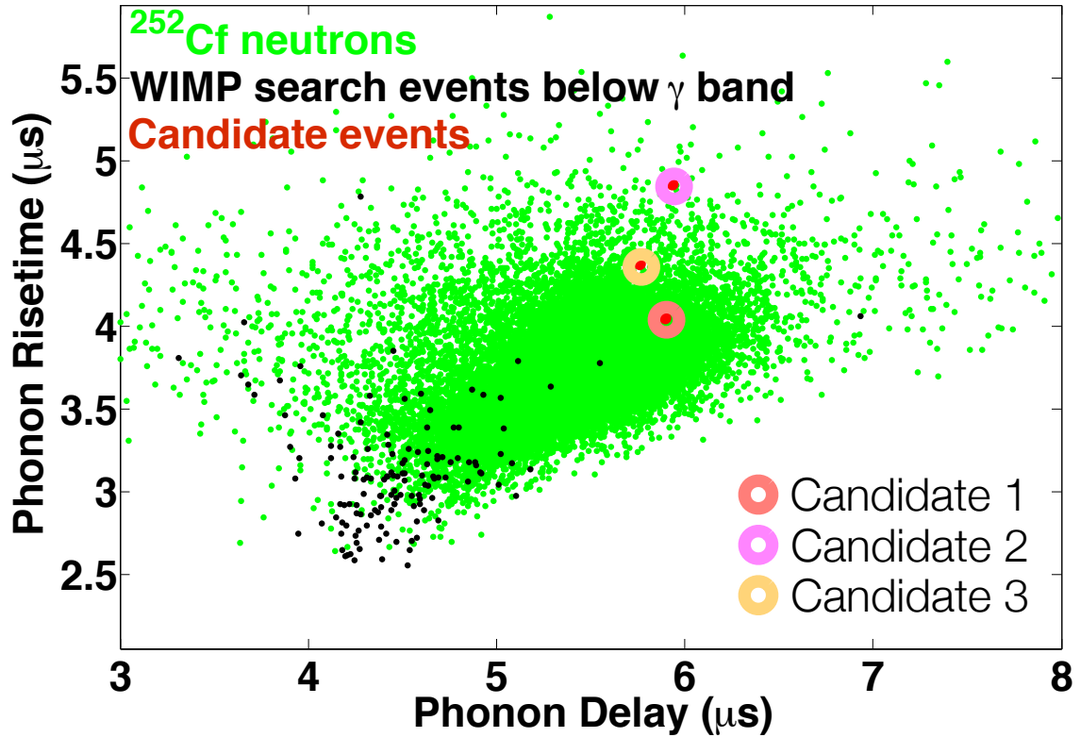
Three events!

Shades of blue indicate the three separate timing cut energy ranges.



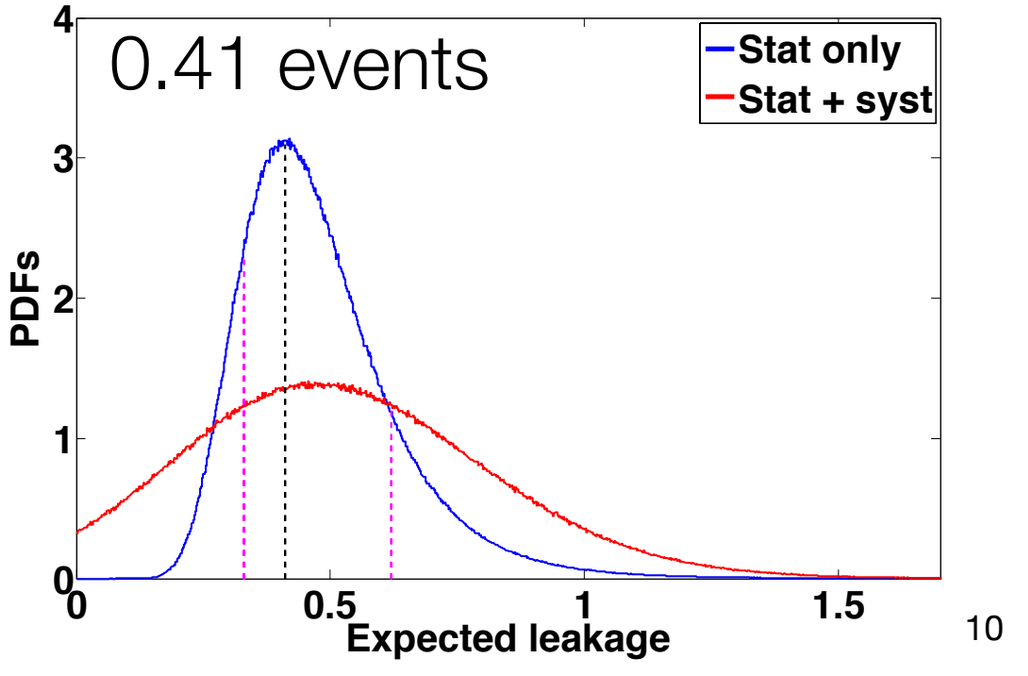
Post-Unblinding Checks

- Consistency checks
  - Events occurred during high-quality data series
  - Events were well-reconstructed
  - Checked energy in other detectors to verify events were single scatters



- Updated background estimates:
  - Cosmogenic and radiogenic neutron:
    <0.13 @ 90% C.L.
  - Surface events

$$0.41^{+0.20}_{-0.08}(stat.)^{+0.28}_{-0.24}(syst.)$$



  - Possible Pb-206 recoils from Po-210 decays

<0.08 @ 90% C.L.

Profile Likelihood analysis

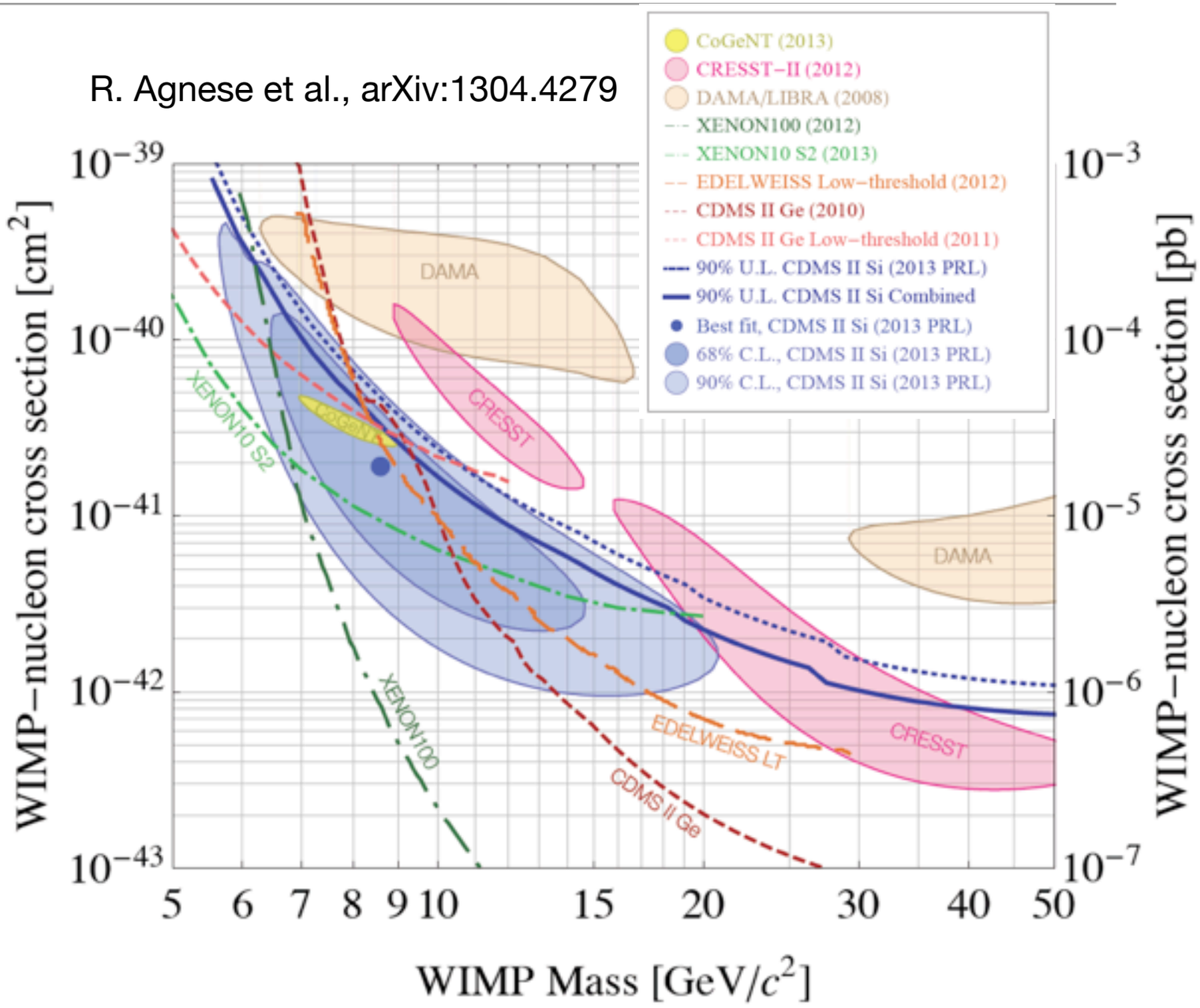
- The maximum likelihood occurs at a WIMP mass of 8.6 GeV/c^2 and WIMP-nucleon cross section of 1.9×10^{-41} cm^2

- Probability of observing 3 or more events from background fluctuations is equal to 5.4%

- Goodness of fit of the WIMP +Background model is 68.6%

- A profile likelihood ratio test statistic favors the WIMP +Background hypothesis over the background only at 99.81% C.L.

R. Agnese et al., arXiv:1304.4279



We do not believe this result rises to the level of a discovery, but does call for further investigation.

SuperCDMS Soudan

See R. Nelson talk

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- 4.6 kg Ge (19 x 240 g)
- 1.2 kg Si (11 x 106g)
- 35% NR acceptance

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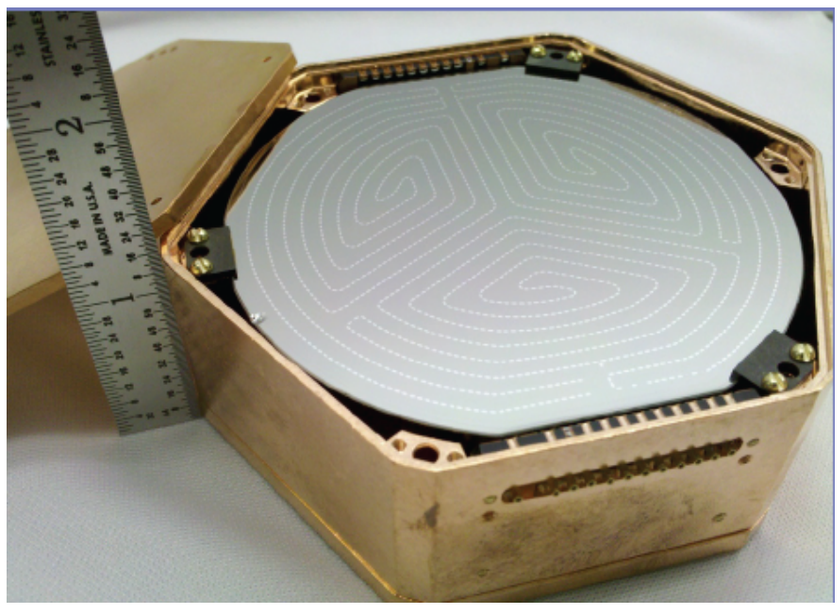
SuperCDMS SNOLAB

- Proposed 200kg Ge array
- Extensive R&D underway
- Scale to 1 kg crystals

Projected sensitivity of 8 x 10^{-47} cm^2

Installation complete Nov. 8, 2011.Detectors have been operating in DM-search mode since March 2012.



SuperCDMS Soudan

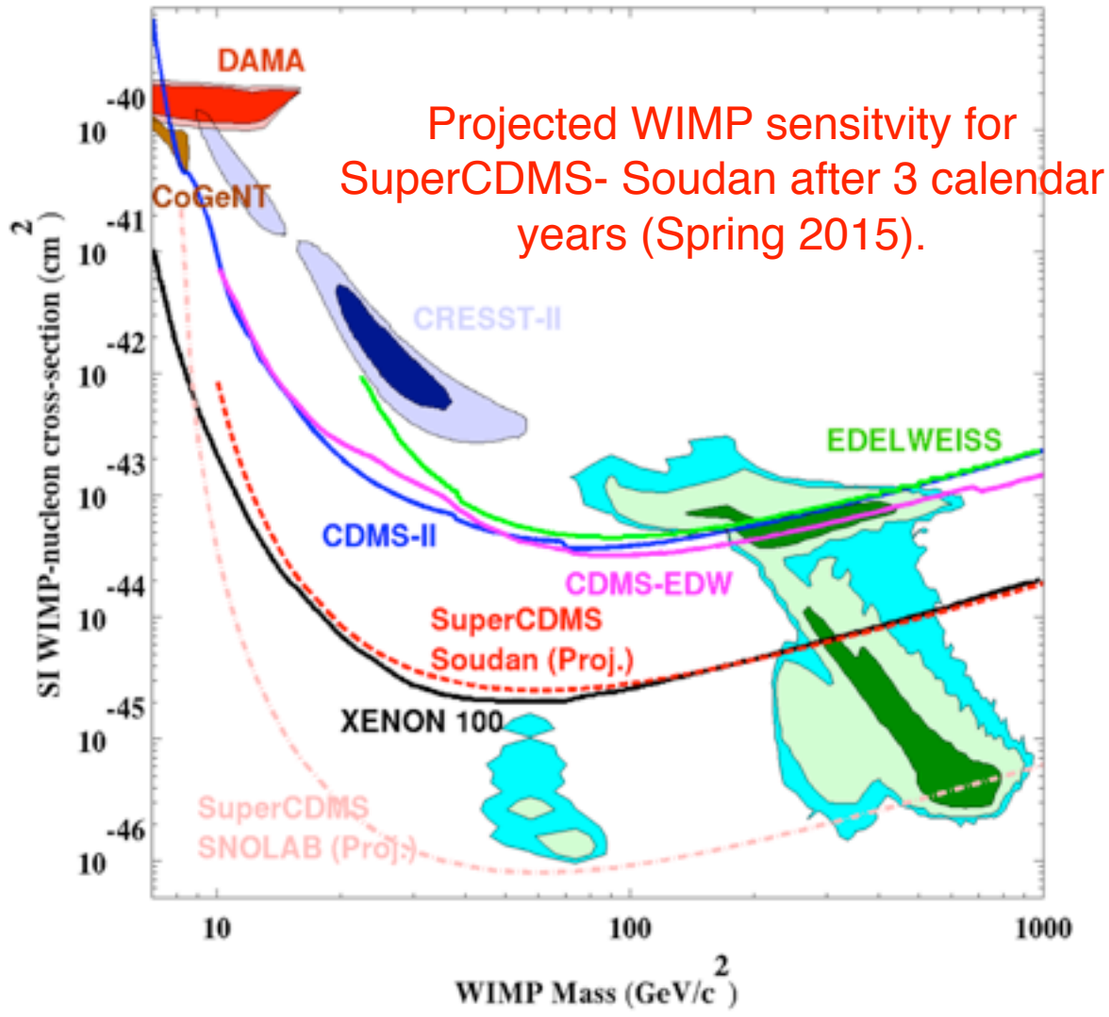
• Array of 15 iZIPs in the Soudan infrastructure built for CDMS-II

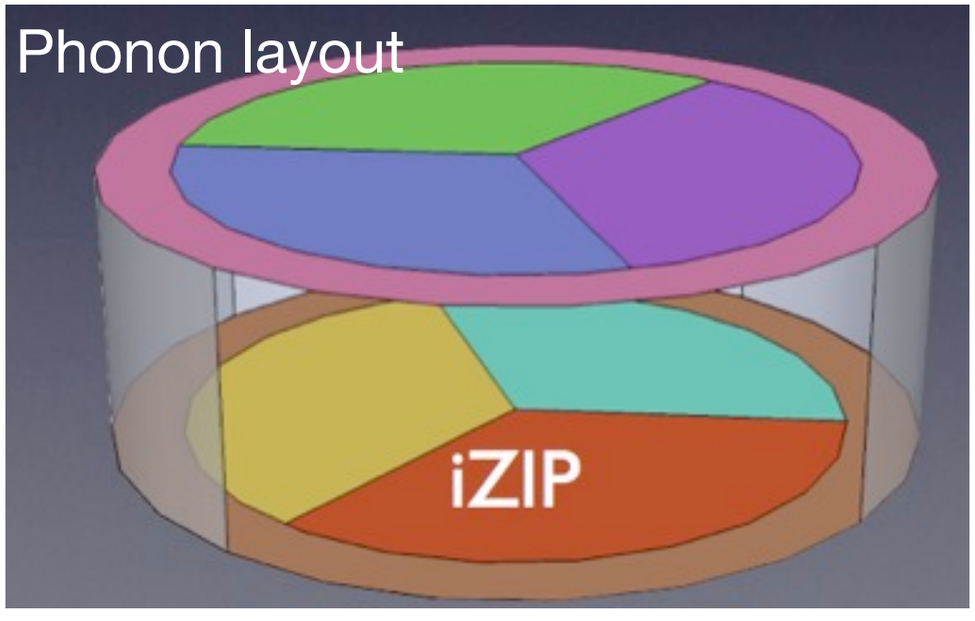
• Factor >x10 sensitivity increase over CDMS-II

- Larger detector mass (x2.5 thicker detectors)
- Fiducial fraction improved to ~50% from 35%
- Surface background negligible

• Interleaved technology allows to get:

- Complex E-field to better tag surface events
- 2 charge electrodes on each side (1 inner + 1 outer)
- 4 phonon channels on each side (3 inner + 1 outer)



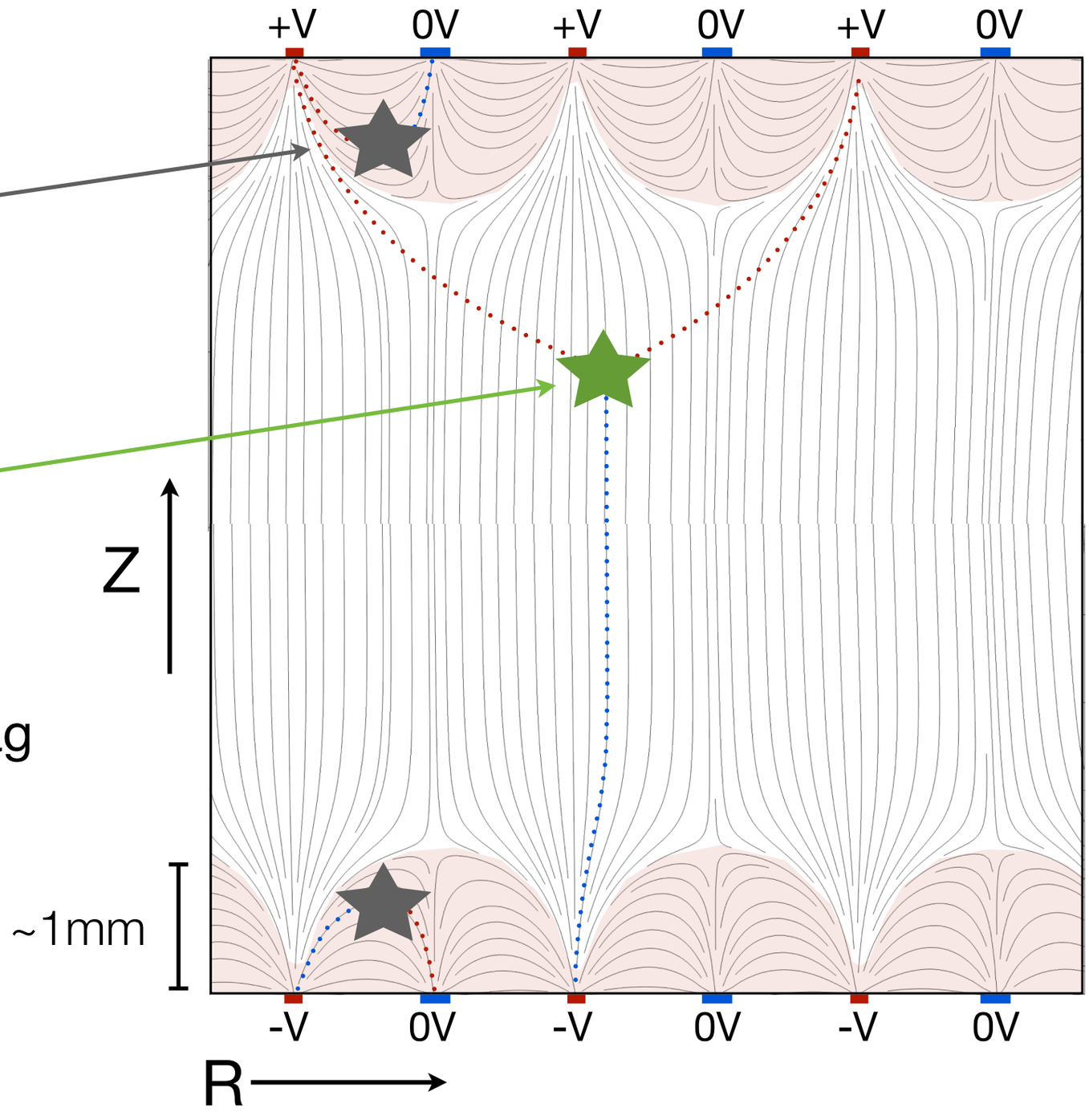


SuperCDMS Soudan: charge discrimination

- Surface events (alpha, betas, nuclei) have ***1-sided*** charge collection

- Bulk events (gammas, nuclear recoils) have ***2-sided*** charge collection

- Charge ***symmetry*** is a powerful tag of surface events on top and bottom sides



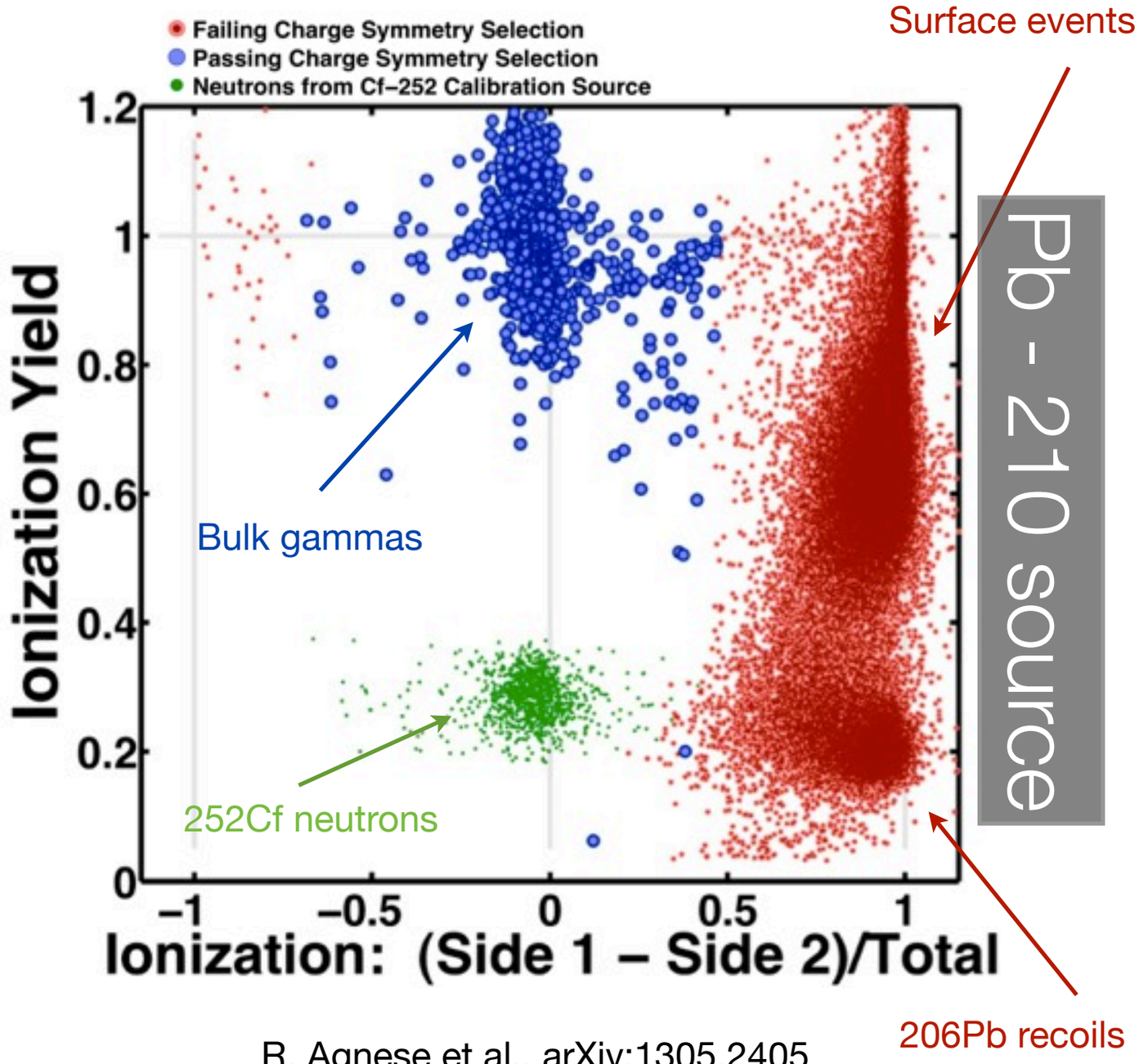
SuperCDMS Soudan: charge discrimination

- ~71,000 electrons and ~16,200 ^{206}Pb recoil surface events collected from ^{210}Pb source.

- No events leaking into the signal region into ~50% fiducial volume (8-115 keVnr) in 37.6 live time days (March - July 2012)

- Limits surface events leakage to 1.7 x 10^{-5} @90% C.L. from 8 to 115 keVnr

- Good enough for a 0.3 ton-year exposure for SuperCDMS@ SNOLAB!



R. Agnese et al., arXiv:1305.2405

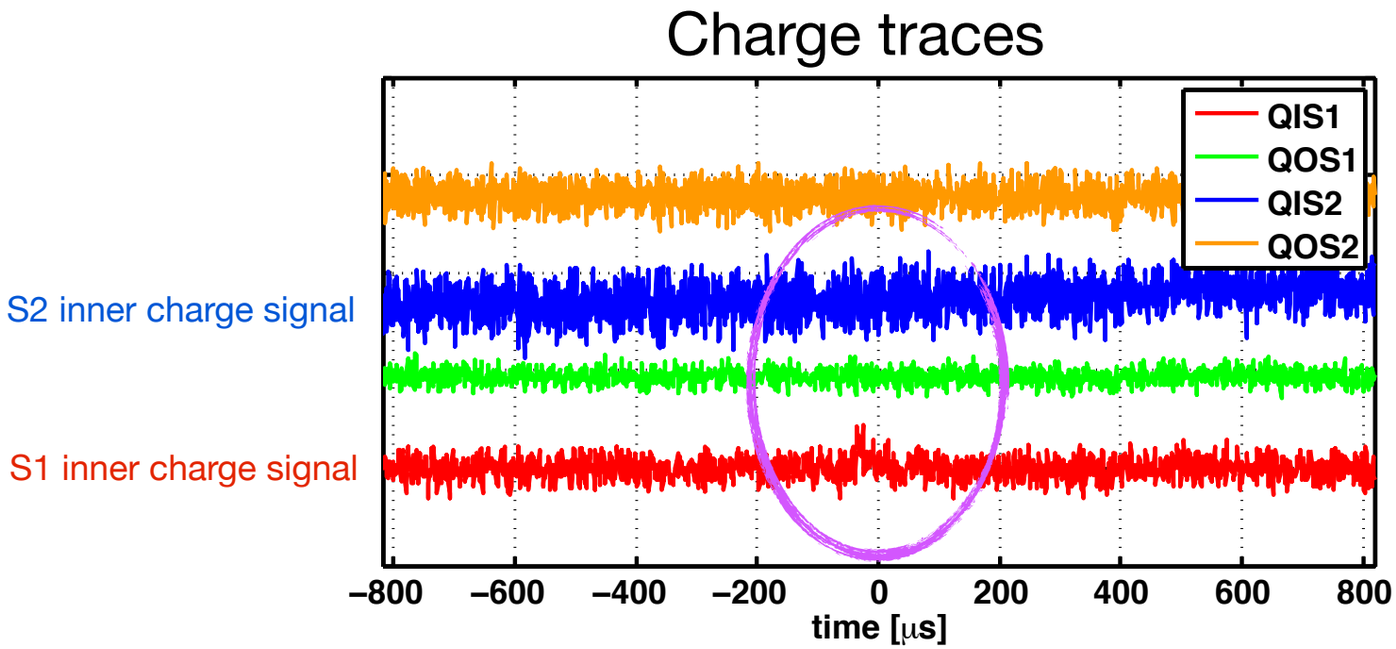
SuperCDMS Soudan: phonon fiducialisation

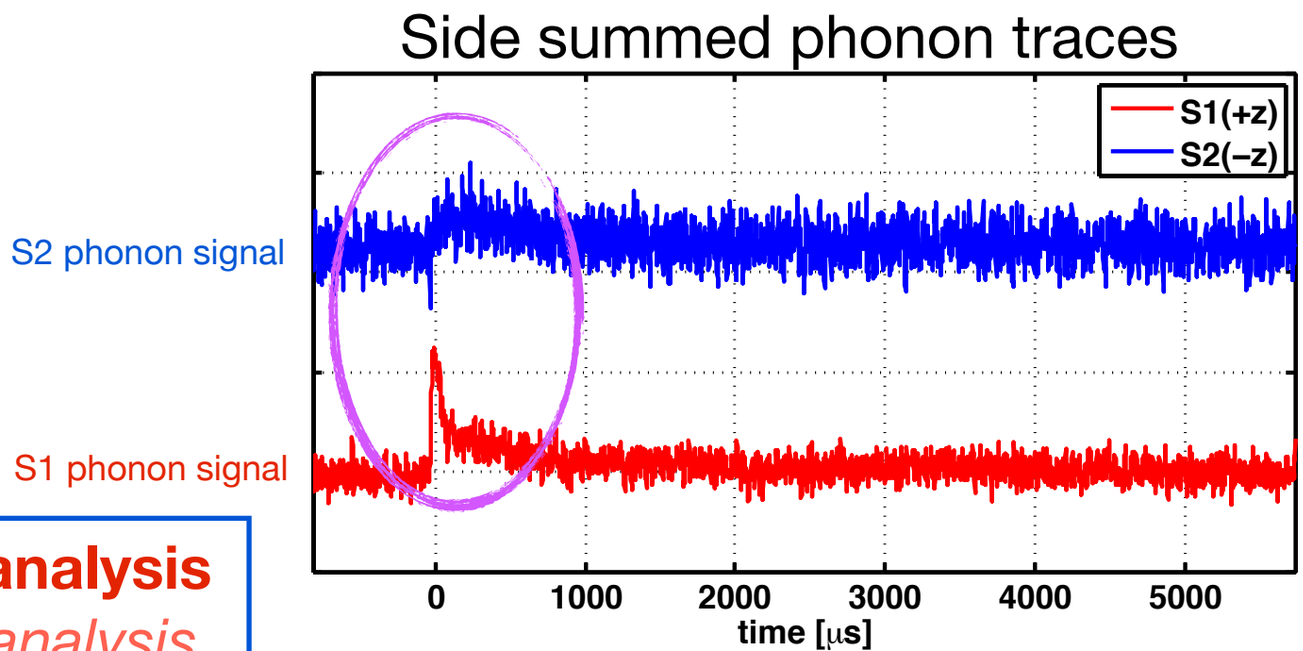
Complex electric field creates asymmetry in both Ionization and **phonon** signals for surface events

Surface event at side 1
4.5 keV phonon energy

- Suface event discrimination using phonon is much more significant at low energies

- Phonon baseline noise is lower than the charge one





Promising for the Low Threshold analysis
Not needed for the High Threshold analysis

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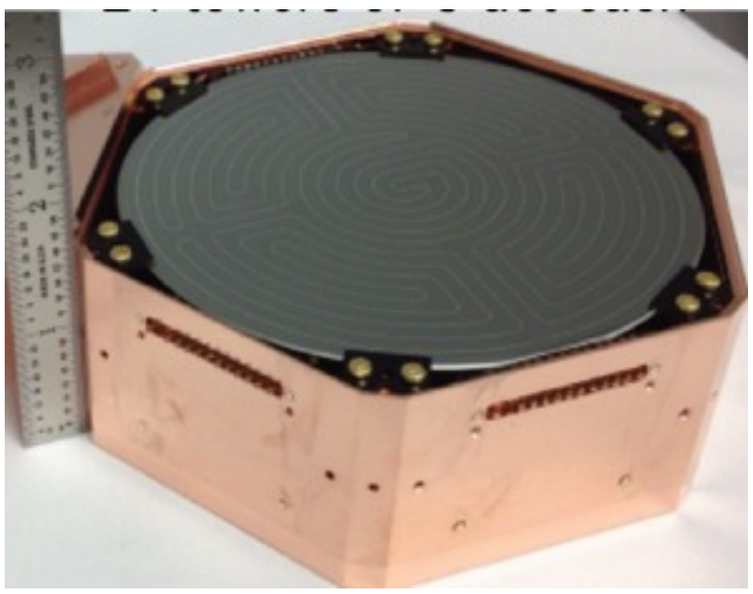
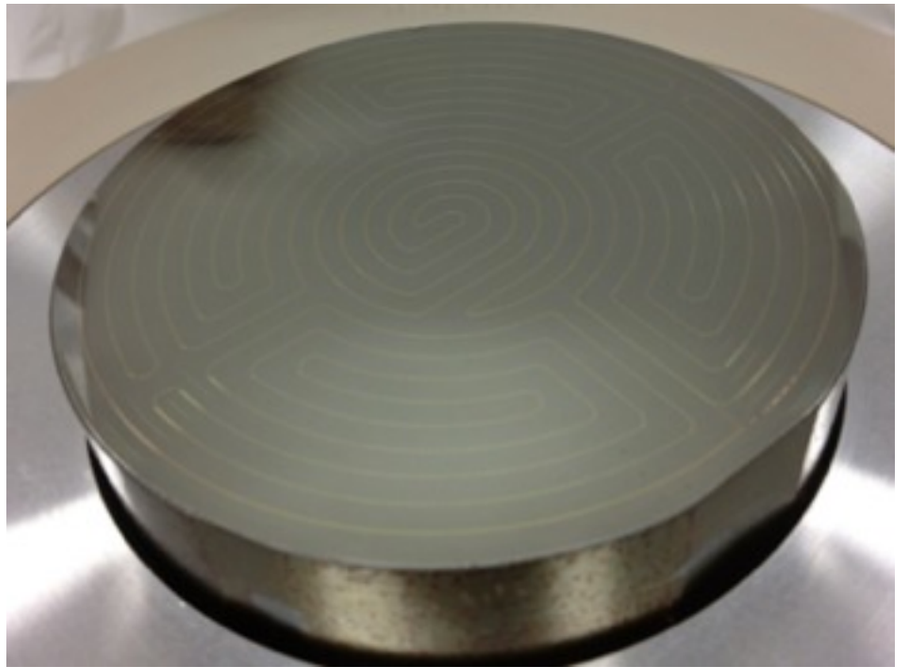


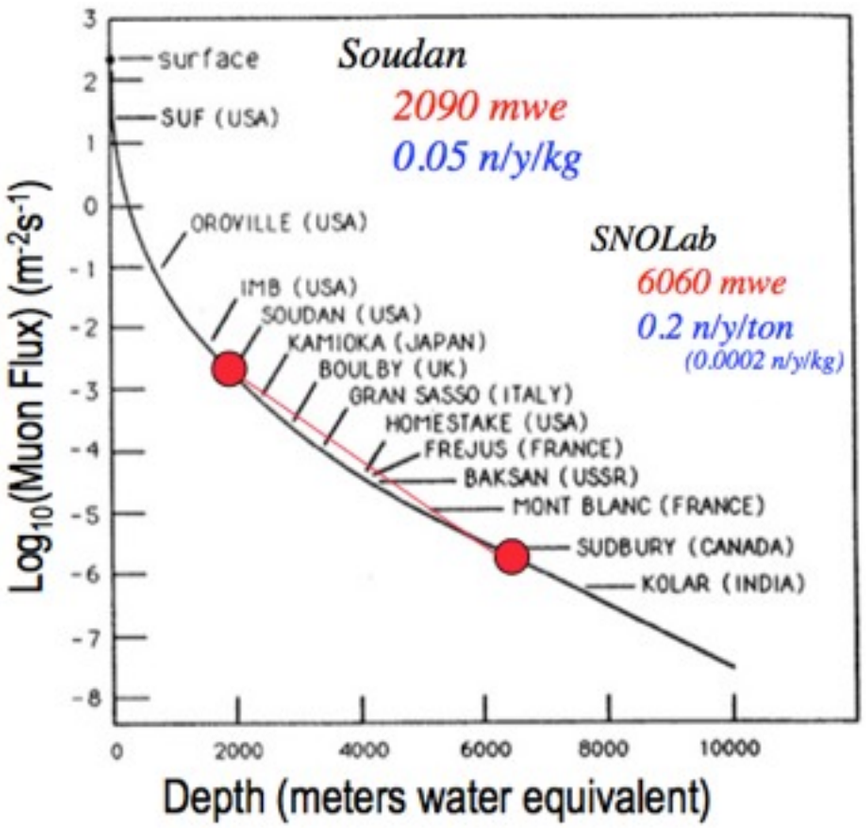
SuperCDMS SNOLAB

• SuperCDMS has proposed a 200 kg Germanium advanced ***interleaved detector*** array for the SNOLAB facility

• Now, seriously considering adding some ***Si iZIPs***



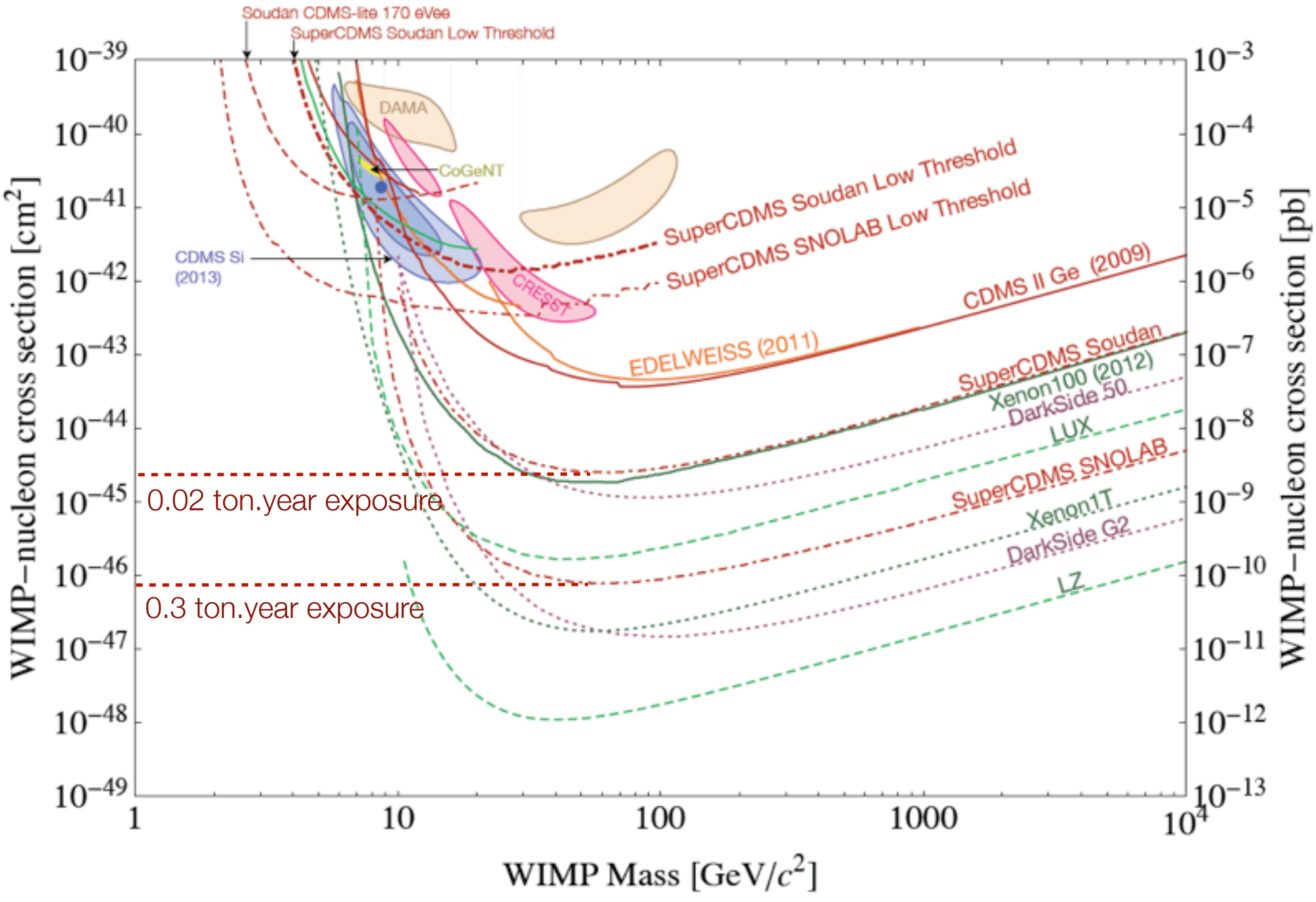
First 100 mm iZIP has been fabricated with new phonon layout. Detector R&D underway



• With such an increase in exposure, we need to go deeper: ***from Soudan to SNOLab***.

• Reduction of cosmogenic neutron background by a factor of 100

SuperCDMS SNOLAB



Conclusion

CDMSII final Si exposure

- Analysis of a 140.23 kg-day exposure of the CDMS-II Si detectors has been performed.
- Three events were seen in the signal region with a total expected background of 0.7 events.
- A profile likelihood analysis favors a WIMP+background hypothesis over the known background estimate as the source of our signal at the 99.81% confidence level (~3σ, p-value: 0.19%).
- We do not believe this result rises to the level of a discovery, but does call for further investigation.

SuperCDMS Soudan/SNOLAB

- SuperCDMS-Soudan (~9 kg) is taking data with iZIP detectors and expects to reach a WIMP-nucleon sensitivity of 2 x 10^{-45} cm^2 for spin- independent interactions.
- We have demonstrated surface event rejection with the new iZIP detector design using ^{210}Pb sources down to 1.7 x 10^{-5} @90% C.L. which paves the way for below than 10^{-46} cm^2 sensitivity at SNOLAB.
- Additional background rejection could be done using phonon pulse shape discrimination (study ongoing)